Cooling of hybrid stars: towards a consistent picture

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We present a set of observational constraints on the cooling behavior of compact stars and discuss possible consequences for structure and composition of their interiors. First, we discuss purely hadronic neutron stars and their cooling [1], focussing on three problems: the *direct Urca problem* [2], the *Vela mass problem* [3] and the *deep crustal heating problem* related to superbursts [4] and X-ray transient cooling [5]. Second, we discuss possible scenarios for hybrid stars with color superconducting quark matter interiors and their cooling behaviour. It is shown that in order to fulfill the cooling constraints, all quark species must be gapped, whereby the smallest diquark pairing gap shall not exceed about 1 MeV [6]. This condition is fulfilled, e.g., for diquark condensation in a single-flavor spin-1 pairing channel, denoted as the isotropic color-spin-locking (CSL) phase [7]. Finally, we discuss a possible realization of this phase in hybrid stars as a down-quark CSL phase in coexistence with asymmetric nuclear matter [8], fulfilling the above cooling constraints and offering a possible source for deep crustal heating as an alternative to previously discussed strange star cores in the color-flavor-locking phase [4].

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[1] D. Blaschke, H. Grigorian and D. N. Voskresensky, Astron. Astrophys. **424**, 979 (2004) [arXiv:astro-ph/0403170].
[2] D. Blaschke and H. Grigorian, Prog. Part. Nucl. Phys. **59**, 139 (2007) [arXiv:astro-ph/0612092].
[3] S. Popov, H. Grigorian and D. Blaschke, Phys. Rev. C **74**, 025803 (2006) [arXiv:nucl-th/0512098].
[4] D. Page and A. Cumming, Astrophys. J. **635**, L157 (2005) [arXiv:astro-ph/0508444].
[5] P. S. Shternin, D. G. Yakovlev, P. Haensel and A. Y. Potekhin, arXiv:0708.0086 [astro-ph].
[6] H. Grigorian, D. Blaschke and D. Voskresensky, Phys. Rev. C **71**, 045801 (2005) [arXiv:astro-ph/0411619].
[7] D. N. Aguilera, D. Blaschke, M. Buballa and V. L. Yudichev, Phys. Rev. D **72**, 034008 (2005) [arXiv:hep-ph/0503288].
[8] D. Blaschke, F. Sandin, T. Klähn and J. Berdermann, arXiv:0807.0414 [nucl-th].

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